ClimaRice Technical Brief 10-2012

Impact of elevated temperature on major pests of rice

CLIMARICE: "Testing Climate uncertainties and validating selected technologies on farmers fields"

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This Technical brief is a short summary of the results obtained from the field trials conducted at Agro Climate Research Centre, Tamil Nadu Agricultural University, India to understand the Pest dynamics at elevated temperature. Among the major food crops, rice (*Oryza sativa* L.) forms the stable food for more than half of the world's population. Among various constrains in rice production, losses due to pest is a major concern. Climate change resulting in increased temperature could impact crop insect pest populations in several complex ways. Although some climate change temperature effects might tend to depress insect populations, most researchers seem to agree that warmer temperatures in temperate climates will result in more types and higher populations of insects. Hence, it is important to understand the population growth of the important insect pests such as yellow stem borer (*Scirpophaga incertulas*) and brown planthopper (*Nilaparvata lugens*) of rice. The results revealed that there was an inverse correlation between temperature and total life span, developmental time and also fecundity. However there was a positive correlation between temperature and net reproductive rate and development rate.

Global warming and Pest biology

Climate and weather can substantially influence the development and distribution of insects. Insects are cold-blooded organisms and hence the temperature of their bodies is approximately the same as that of the environment. Therefore, temperature is probably the single most important environmental factor influencing insect behavior, distribution, development, survival, and reproduction. The last assessment report from the Intergovernmental Panel on Climate Change (IPCC) predicts an increment in mean temperature from 1.1 to 5.4° C toward the year 2100 (IPCC, 2007). It has been estimated that with a 2°C temperature increase insects might experience one to five additional life cycles per season (Yamamura and Kiritani, 1998). Porter *et al*. (1991) listed the effects of temperature on insects which limit their range, overwintering, population growth rate, number of generations per annum, length of growing season, crop-pest synchronization, intraspecific interaction, dispersal, migration and availability of host plants and refugia.

Experimental details

Research investigations were conducted to study the influence of increasing temperature on pest population dynamics of rice (*Oryza sativa* L.) under climate control chamber, Agro Climate Research Centre, Tamil Nadu Agricultural University. The experiment location having the climate of Semi-Arid Tropics experiences a mean annual rainfall of 674.2 mm distributed over 48 rainy days. The mean maximum temperature and minimum temperature are 31.5°C and 21°C respectively.

Fig.1. Overview of Climate Control Chamber

Insect culture:

Insect rearing is a complex and specialized field. It is a backbone of modern experimental entomology. The development of new pest control strategies depends upon our ability to rear and manage quality insects in the insectary. BPH (*N. lugens*) and YSB (*S. incertulas*) were used as the test insects during the investigation.

Brown Plant Hopper

The nucleus cultures of planthoppers were collected from the paddy fields of Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore. In order to maintain an uniform and continuous culture of the hoppers, the insects were mass cultured using potted TN1 rice plants. Ten days old TN1 rice seedlings were transplanted

in plastic pots (30 cm dia and 45 cm height) at the rate of five seedlings per pot. Thirty days after transplanting, the plants in individual pots were cleaned and outer leaf sheaths were removed to destroy any possible oviposition by other insects. The plants were then covered with cylindrical mylar film cages (9cm dia; 45cm height) with fine mesh screen windows. About thirty to forty gravid hopper females along with five to ten males were released inside each mylar cage for oviposition. The potted plants provided for oviposition were replaced every two days with new sets of plants of similar age. The oviposited plants were transferred to a wooden cage (45 x 45 x 60 cm) and watched for hatching of the eggs. This phenomenon was followed throughout the experimental period and thus continuous availability of the test insects was obtained. During the whole process of culturing, the potted plants were placed in galvanized iron trays with ten cm depth of water. The plants that showed wilting due to nymphal feeding were renewed regularly from the rearing cage.

Fig. 2. Brown Plant Hopper mass culture

Yellow Stem Borer:

For getting uniform population of *S. incertulas* mass culturing was done by following the method described by Chandramohan (1983). As it was difficult to mass culture the insect under green house conditions the requisite population of *S. incertulas* adults were collected from the rice fields of Paddy Breeding Station when necessary. The collected moths were confined four to five days old plants grown in clay pots of seven cm height and ten cm dia. The next day, the leaves with egg masses were clipped and confined in a 7.5 x 2.5 cm glass tube till completion of the incubation period and the larvae that hatched were used for further studies.

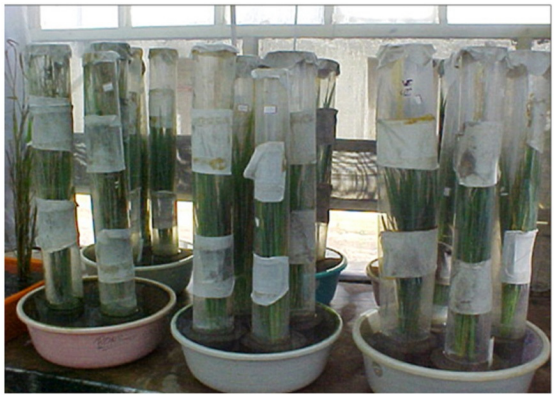
Measurment of Life History Parameters

Experiments were carried out with an aim to estimate the duration of different stages of insects, to compare the proportion of duration of different stages in its life span and to analyse the probability of its survival and fecundity under increasing temperature *viz.*, 30, 32, 34, 36 and 38^0C.

Brown Planthopper (BPH)

Thirty day old rice plants in a pot were placed on the floor of the insect cage. One gravid female adult BPH was released into each insect cage. The total numbers of eggs laid were recorded daily until the all released BPH females had died. The eggs were counted using a magnifying glass. Otherwise calculated from the number of emerging instars. Emerging BPH nymphs were maintained in mylar cages as and observed daily until their death (Fig.3). Life history traits such as survival, fecundity, development time and longevity were recorded at different temperatures.

Fig.3. Oviposition cage to observe fecundity rate of BPH



To study nymphal survival (NS), ten first instar BPH nymphs were released on 35 days old caged plants. The number of nymphs that reached adulthood was counted and the percentage of nymphal survival was calculated (Heinrichs *et al.*, 1985). Developmental period (DP) of nymphs was studied by releasing three first instar nymphs on 35-day old caged plants. The nymphs were observed daily for ecdysis and the number of days taken for the nymphs to reach the adult stage was recorded (Pong Prasert and Weerapat, 1979).

Adult longevity (AL) of BPH males (ALM) and females (ALF) was studied by releasing three pairs of newly emerged adults on 35 days old caged plants. The adult BPHs were observed daily for their survival. Upon mating adulthood, the surviving BPH were sexed and fecundity of each female was counted daily.

Yellow stem borer (YSB)

This study was carried out first by collecting the female moths from the paddy fields and the moths were kept separately each in an insect cage (Height - 2 ¾ feet, Width - 2 ½ feet, Length – 2 ½ feet, Netted in three side) with 1 month duration crop of paddy in a pot under 5 different temperatures for egg laying (Plate 3b). Date of hatching and percentage of egg hatch were recorded. Egg masses with leaves were kept in a Petridishes in incubator to maintain temperatures. To prevent drying, the one end of which was covered with moist cotton. Observations of these eggs were made till they hatched and the incubation period of these eggs was determined under different temperatures. Then freshly emerged larvae were kept separately by introducing them in a piece of rice stem, covered with moist cotton at one end to prevent drying. The rice stem with larvae inside were kept separately in test tubes of 5x1cm size, plugged with cotton and all the tubes were kept under different temperature conditions. The rice stems of which the larvae fed were changed every day during which the observations were made on the development of the caterpillars. The pupae were observed by carefully opening the rice stems in which the larvae pupated. Before emergence of the moths about two or 3 days the pupae were kept outside the rice stems but still remaining in the test tubes for easy observation until the adults emerged.

Fig.4. Oviposition cage to observe fecundity rate of YSB

For the study of longevity of adults, freshly emerged moths both male and female were kept together in a glass cage provided with rice seedlings for mating. By observing the first laying of eggs by the female moth, the pre-oviposition period was back calculated, and these eggs were observed till they hatched. By observing the period between the emergence and death of the adults the longevity period was calculated.

Statistical analysis

The effect of temperature on life stage durations was analyzed at each life stage by using one way analysis of variance (ANOVA). Within instars, one way ANOVA was performed to analyze the effects of temperature on life stage duration. Percentage of egg hatch was analyzed as a two way ANOVA to test for the effects of temperature and time. Percentage data were converted using arcsine transformation, but values are presented as untransformed means (Sokal and Rohlf, 1995). All statistical analyses were performed using AGRES software.

Results

Duration of different stages

In general, the duration of different stages of yellow stem borer under varying temperatures varied significantly (Table 1). YSB took 8.1 mean days for hatching out into larvae at 30°C. However at higher temperature it was found to be decreased. In the same way larval and pupal period showed a decrement. Like YSB, the same trend was observed in BPH (Table 1). BPH took 6.7 mean days for hatching out into nymphs. However this period decreased significantly at higher temperature. Decreased developmental duration of instars observed at increasing temperatures might be connected with faster larval growth at these temperatures. Insects develops faster will oviposit early and hence the population will grow earlier than expected.

Life stage (days)	Temperature (°C)			
	YSB		BPH	
	30	38	30	38
Egg	8.10^{a}	7.08^{c}	6.7^{b}	6.0^{e}
Larva / Nymph	25.88^{a}	20.18^{d}	15.4^{a}	11.2^{e}
Pupa	6.08^{a}	6.23^{a}	-	-
Immature	40.15^{a}	32.78^{e}	22.4^{a}	18.2^{e}

Table 1. Development of YSB (*S. incertulas*) and BPH (*N. lugens*) immature stages under increasing temperature

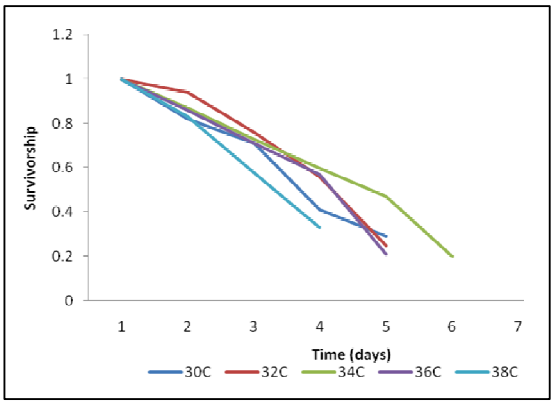
Survivorship:

Slobodkine (1966) stated that four types of relationships exist to describe the survival of an

animal in function of time viz., logistic, linear, logarithmic and exponential. These shapes are characterized by the mortality patterns of the animals. In the case of YSB as well as BPH the mortality is characterized by a constant number of deaths per unit time and the survival curve tends to be linear (Figure 5 and 6).

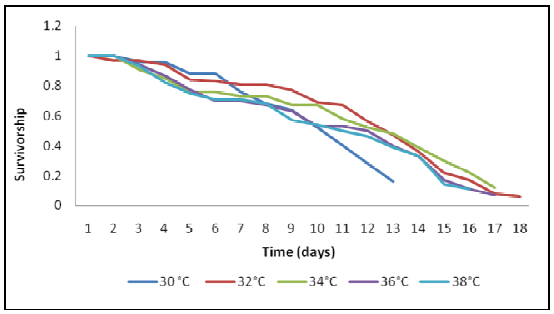
In the case of YSB, 50 per cent mortality occurred between 3 – 5 days. Since the duration getting started at higher temperatures, significant shift at the mortality pattern was shown. Generally, YSB live shorter period of time when the temperature goes higher.

Fig.5. YSB (*S. incertulas)* female survivorship under increasing temperatures



The linear pattern of survivorship is more pronounced in BPH than YSB. As in the case of YSB, BPH also survived shorter duration when the temperature goes higher. Consequently there was a shift in 50 per cent mortality in between 10 – 13 days. At higher temperature, BPH died faster than at lowest temperature.

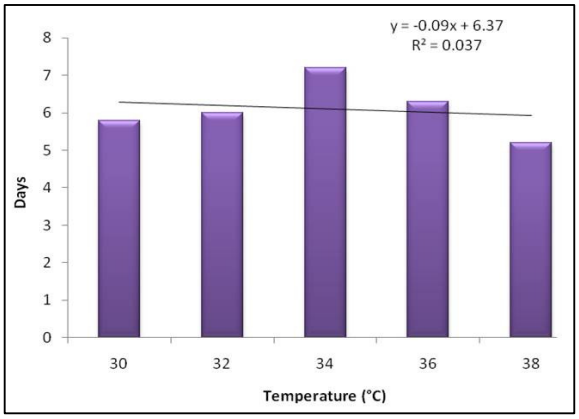
Fig.6. BPH (*N.lugens*) female survivorship under increasing temperatures



Developmental time and longevity

The mean developmental time is defined as time taken by individual to become an adult. On the other hand the longevity is defined as the length or duration of entire life. Negative correlation was observed between the developmental time and temperature. Similarly negative correlation was also obtained between longevity and temperature in both YSB and BPH. YSB took 40.15 days duration before adult stage at 30°C. However, it took 32.78 days to develop into adult at 38°C (Table 1). However the YSB lived out its life in 6.0 days at 30°C and lived only 5.2 days at 38°C (Figure 7).

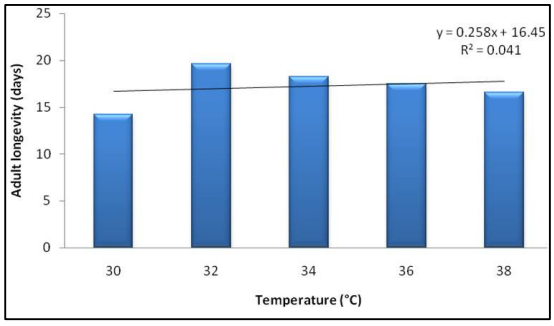
Fig.7. YSB (*S. incertulas*) adult female longevity under increasing temperatures



The same trend was observed in BPH. BPH took 22.4 days to become adult at 30°C. However it took 18.2 days to develop into adult at 38°C (Table 17). However, BPH lived out its life in 19.58 days at 32°C and lived only 16.58 days at 38°C (Figure 8).

Fig.8. BPH *(N. lugens)* adult female longevity under increasing temperatures

Development rate



The development rate is defined as the rate at which the individual grows. It was calculated by using the formula *i.e.* 1/duration of life stage. Generally both YSB and BPH tend to develop at faster rate at higher temperature than the lower

temperature. In the case of YSB, the developmental rate at 30°C was 0.2513, whereas it was 0.03032 at 38°C (Table 2). In the case of BPH, the development rate at 30°C was 0.0446, whereas it was 0.05519 at 38°C (Table 2).

Table 2. Effect of temperature on development rate of YSB and BPH

Temperature (°C)	Development rate	
	YSB	BPH
30	0.02513[d]	0.04461[d]
32	0.02704[c]	0.05048[c]
34	0.02875[b]	0.05175[b]
36	0.03031[a]	0.05411[a]
38	0.03032[a]	0.05519[a]

Life history parameters

Life and fecundity table for YSB and BPH were established as per the principles explained from the results of other experiments. A composite summary of different life history of YSB and BPH are presented in Table 3 and 4, respectively. Detailed age specific life and fecundity tables of YSB and BPH at different temperature are presented in Table 29 and 30, Plate 11 and 12.

Table 3. **Life history parameters of YSB (*S. incertulas)* under increasing temperature**

Parameter	Temperature (°C)	
	30	38
Age of first oviposition	42[a]	34[d]
Age of last oviposition	45[a]	38[d]
Age of maximum oviposition	43[a]	35[d]
Length of oviposition period	4[b]	5[a]
Net reproductive rate (R_O)	42.79[c]	38.73[d]
Gross reproductive rate(GRR)	293.17[b]	243.87[e]
Generation time (T)	44.05[b]	35.48[e]
Intrinsic rate of increase(Rm)	0.0846[e]	0.1034[b]
Finite rate of increase (λ)	1.0882[e]	1.1091[b]
Doubling rate (DT) NS	8.19[a]	6.71[d]

4.8.1. Yellow stem borer

Value of intrinsic rate of natural increase (r_m) at 30°C was 0.0846 and this parameter was found to be increased at in increasing temperatures (Table 3). These permits to find out finite rate of increase which defines constant by which the population is expected to multiply in each day. Since the growth rate increased with the increasing temperatures, the population of YSB doubles at faster rate. At a constant temperature of 30°C, the population of YSB doubles in 8.19 days, whereas it doubles in 6.71 days at 38°C. Net reproductive rate (Ro) was 42.79 individuals and the generation time (T) was 44.05 days at 30°C. However, at 36°C Ro was 51.0 individuals and T was 37.56 days. In other words, if one assumes at the birth where constant at one moment, consecutive generation will be separated in 44.05 days at 30°C and 37.56 days at 36°C or YSB increases 42.79 times in 44.05 days at 30°C and 51 times in 37.56 days at 36°C. Thus the population of YSB, at higher temperature reproduces more in short duration.

4.8.2. Brown planthopper

Table 4. Life history parameters of BPH (*N. lugens*) under increasing temperature

Parameter	Temperature (°C)	
	29-30	38
Age of first oviposition	25[a]	22[d]
Age of last oviposition	36[a]	32[c]
Age of maximum oviposition	31[a]	30[b]
Length of oviposition period	12[b]	11[a]
Net Reproductive Rate (R0)	64.43[b]	77.71[a]
Gross Reproductive Rate (GRR)	284.89 [b]	376.68[a]
Generation Time (T) NS	29.56	28.27
Intrinsic Rate Of Increase (Rm)	0.1398 [d]	0.1541[a]
Finite rate of increase (λ)	1.1495 [c]	1.1664[a]
Doubling rate (dt)	4.93[a]	4.50[b]

Value of intrinsic rate of natural increase (r_m) at 30°C was 0.1398 and this parameter was found to be increased at increasing temperatures (Table 4). These permit to find out finite rate of increase which defines constant by which the population is expected to multiply in each day. Since the growth rate increased with increasing temperatures the population of BPH doubled at faster rate. At a constant temperature of 30°C, the population of BPH doubles in 4.93 days where as it doubles in 4.50 days at 38°C. Net reproductive rate (Ro) was 64.43 individuals and the generation time (T) was 29.56 days at 30°C. However, the same was 77.71 individuals and 28.27 days at 38°C. In other words if one assumes at the birth where constant at one moment consecutive generation will be separated in 29.56 days at 30°C and 28.27 days in 38°C or BPH increases 64.43 times in 29.56 days at 30°C and 77.71 times in 28.27 days at 36°C. Thus the

population of BPH at higher temperature reproduces more in short duration.

Conclusion

Investigations in the insect pests of rice revealed that there was an inverse correlation between temperature and total life span, developmental time and also fecundity. However there was a positive correlation between temperature and net reproductive rate and development rate. In the same way survival of pests also had a negative correlation with temperature. In case of YSB and BPH, total life span at 38°C decreased significantly than at 30°C. Faster development rate of YSB and BPH was noticed at 38°C than 30°C.

At higher temperature of 36°C the net reproductive rate was higher and the generation time was shorter compared to 30°C in YSB. In the case of BPH the NRR was significantly higher at 38°C and the generation time was shorter compared to 30°C.

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CLIMARICE Project (2010-2012)

ClimaRice **is** an integrated project that aims to assess the climate variability and its impacts on the water availability and rice production systems in the Cauvery and Krishna river basin of Tamil Nadu, India. The overall goal is to contribute to the regional and national adaption strategies to sustain rice production and ensure food security amidst changing climate. The partners are:

- Bioforsk - Norwegian Institute for Agricultural and Environmental Research (Project Co-ordinator)
- Tamil Nadu Agricultural University, Coimbatore, India
- International Pacific Research Institute, Hawaii, USA
- International Water Management Institute, IWMI, Hyderabad, India.

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